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Personnel Research Report

THE FACTORIAL COMPOSITION OF
THE RELATIVE MOVEMENT TEST

by
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and
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EDUCATIONAL TESTING SERVICE
PRINCETON, NEW JERSEY
JULY 1953

Sponsored by the Bureau of Naval Personnel
and the Office of Naval Research

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Abstract

The present study was undertaken to determine what abilities are measured by the Relative Movement Test, which is a part of the U. S. Navy Officer Classification Battery. Better understanding of this test may lead to improvements which will result in more effective selection and classification of officer personnel. A factor analysis was performed based on the interrelationships of the tests in the Officer Classification Battery, some new experimental tests, tests of plotting, standard tests of known abilities, and three separate forms of the Relative Movement Test -- (1) the regular form, (2) the regular form counting only the first 20 items (which practically all candidates completed), and (3) the pretest of a new parallel form which had a liberal time allowance.

The findings with respect to what is measured by the Relative Movement Test were as follows:

1. Students who do well on Relative Movement tests also are likely to do well on Mathematics Reasoning tests, Verbal tests, and tests requiring ability to deal with changes in distance and direction of objects moving in two-dimensional space. This latter ability was also found in plotting tests and may be called Spatial Reference.
2. Mathematics Reasoning ability is most important for success on both the regular form and the 20-item form of Relative Movement. Verbal and Spatial Reference abilities, having approximately equal weightings, are next in importance.
3. In addition to the abilities of Mathematics Reasoning, Spatial Reference, and Verbal, the unspeeded pretest of items for the new parallel form of Relative Movement also appears to require the ability to deal with complex instructions or to grasp the elements of a fairly complex problem situation.

Mathematics Reasoning and Spatial Reference are the most important abilities required for success on this form; least important is Verbal ability.

It is recommended that a validity study be performed of Spatial Reference tests, similar to the plotting tests, in order to establish the utility of such tests for increasing the predictiveness of the Officer Classification Battery.

Acknowledgments

Acknowledgment is made to a number of persons whose interest and cooperation have made this research possible.

Dr. John T. Dailey, Technical Director of Personnel Analysis Division, Bureau of Naval Personnel, proposed the research and made various suggestions regarding methodology.

Captain Ralph C. Johnson, Commanding Officer, U. S. Naval Schools Command, U. S. Naval Station, Newport, Rhode Island, made possible the testing which was carried out at the Officer Candidate School.

Lieutenant Commander George E. Strother, Interviewing Officer, capably arranged and coordinated the special administration of the test battery.

Dr. Ledyard R. Tucker, Research Associate at Educational Testing Service, offered valuable guidance and advice at various phases of the research.

The Matrix Rotator, which was made available to Educational Testing Service by the Adjutant General's Office, made possible the relatively quick and efficient rotation of the reference axes to produce a sample structure. Mr. Harry Harman, Chief, Statistical Research and Analysis Section, Personnel Research Branch, and his staff gave valuable assistance in connection with the operation of the Matrix Rotator.

Miss Elizabeth Connor, Statistical Assistant, did all the necessary computing in connection with the extraction of the factors.

THE FACTORIAL COMPOSITION OF THE RELATIVE MOVEMENT TEST

Introduction

Chapter 7 of Stuit's book (4) indicates that an earlier form of the Navy's Relative Movement Test was found to be a good predictor of success in training programs concerning radar, fighter director, and sonar. Partly because of these findings and partly because it was found not to correlate highly with other tests in the battery, the present form of the Relative Movement Test was later incorporated into the U. S. Navy Officer Classification Battery. This battery also includes tests of mathematics, verbal reasoning, mechanical comprehension, block assembly, and block recognition. The present study was undertaken in order to secure more adequate information concerning the psychological functions measured by the Relative Movement Test.

A factor analysis of a battery of reference tests, including Relative Movement and other tests in the Officer Classification Battery, was therefore performed to obtain more precise knowledge of what the test measures. Better understanding of the psychological functions measured by the Relative Movement Test would aid in the development of selection and classification measures which take full advantage of any abilities measured by Relative Movement and which are not represented in other tests of the Officer Classification Battery.

Procedure

The factor analysis was based on 30 test scores obtained for 666 officer candidates enrolled in Class 7 of the Officer Candidate School at the U. S. Naval Station, Newport, Rhode Island. Included in the analysis were scores for the Relative Movement Test and four other Officer Classification Battery tests. Also included were scores for a test in Operations which is administered during the Operations course at the school. Scores for the remaining 24 tests

used in the analysis were obtained from a special administration of a battery consisting of standard factorial reference tests and several newly developed tests.

Scores used in the analysis were obtained from the following tests (variable numbers appear in parentheses):

(18) Relative Movement. The 50 items of this test consist of statements about the maneuvers of one or more ships in terms of speed, direction, distance, and time. Examinees are required to choose, without the aid of plotting or calculating on paper, the correct answer from the four alternatives presented. Alternatives are stated in terms of a bearing, a course, or a relative speed or distance. The following serves to illustrate the general character of the items:

Ship A is steering northeast at 15 knots against a current of 3 knots. At 5 o'clock a lookout on Ship A sights Ship B 3 miles directly west. At 6 o'clock Ship A steers north. At 7 o'clock Ship B is detected 9 miles to the southeast. Ship B's course is:

- (1) southeast (2) northeast (3) north
- (4) it is impossible to tell from these data.

Working time, 30 minutes.

(32) Relative Movement (part-score). In a previous study of the Relative Movement Test (3, pp. 3-4), there was some evidence that the test is a speeded measure; the answer-sheets indicated that most examinees did not get beyond Item-25 in the 30 minutes assigned to the task. In light of this finding, a part-score for the test, based on the first 20 items, was included to the extent that it appears in the table of test intercorrelations and in the tables of factor loadings. This variable, however, was not used for the purpose of factor extraction. It was included to permit a comparison between the part-score and the whole-score with respect to factorial composition.

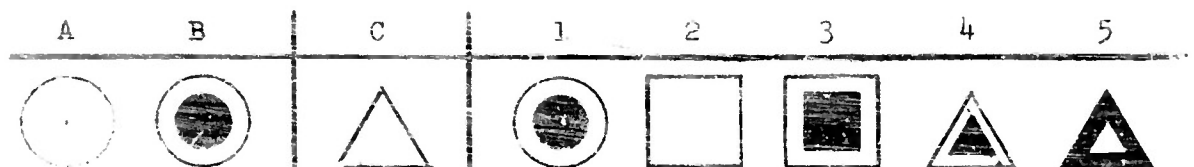
(31) Relative Movement (pretest of alternate Relative Movement items). In the course of developing an alternate form of Relative

Movement, an unspeeeded pretest of new Relative Movement items had been administered to the same Officer Candidate group who took the tests for the present factor study. The pretest was administered primarily to obtain item-analysis data and was included in the present analysis to the extent that it appears in the table of inter-correlations and in the tables of factor loadings. As in the case of the part-score of Relative Movement, this variable was not used in extracting factors. It was included to permit a comparison between the operational form of Relative Movement and the unspeeeded pretest of Relative Movement items. A comparison between the two might reveal what effect, if any, speeededness has on the factorial composition of Relative Movement.

(1) Mathematics. This test is part of the Officer Classification Battery and was included in the analysis as a reference test for the General Reasoning factor. Its 50 items consist of problems requiring arithmetic and algebraic operations and some knowledge of geometry or trigonometry. Examinees are required to solve each problem and then to indicate which one of the four given alternatives represents the correct solution. Working time, 50 minutes.

(2) Figure Analogies. This was included as a second reference test for the General Reasoning factor. In each of 30 items, examinees are required to recognize which one of five drawings is related to Drawing C in the same way that Drawing B is related to Drawing A.

Example:



Working time, 15 minutes.

(3) Letter Sets. This test was included as a reference test for the Inductive Reasoning factor. Each of the 20 items consists of five groups of letters. For each item examinees are required to discover what characteristic four of the letter groups have in common and to indicate the one group that does not fit the rule. Example:

(1) ABCD (2) LMNO (3) MNOP (4) DEFT (5) UVWX

Working time, 10 minutes.

(4) Locations. This test was also included as a reference test for the Inductive Reasoning factor. Each of the 30 problems consists of five lines of small dashes separated into groups of dashes or "words" by blank spaces. In each of the first four lines a dash is replaced by an "x"; in the fifth line, five of the dashes are replaced by numbers. Examinees are required to discover the rule governing the placement of the "x" in each of the first four lines and to apply the rule in deciding at which of the numbered positions the "x" should be in line 5. Example:

```
-----x-----
-----x-----
-----x-----
-----x-----
-----1--2--3--4 5---
```

Working time, 10 minutes.

(5) Vocabulary. Included as a reference test for the Verbal factor, this 60-item vocabulary test is identical with Part I of the Cooperative English Test C2, Reading Comprehension, Form Y. For each item examinees are required to select one word out of five alternatives that corresponds in meaning to a given word. Working time, 15 minutes.

(6) Verbal Reasoning. This test is part of the Officer Classification Battery and was also included in the analysis as a reference test for the Verbal factor. The 75 items are of the verbal analogy type. Working time, 35 minutes.

(7) Block Assembly. A part of the Officer Classification Battery, this test was included as a reference test for the Spatial Relations factor. Each of the 30 items presents three-dimensional drawings of three or more blocks and requires the examinee to indicate which one of four figures could be constructed from the given blocks. Working time, 15 minutes.

(8) Block Recognition. This test is also a part of the Officer Classification Battery. Each of the 60 items of this test of the Spatial Relations factor presents a drawing of a solid figure called the "key block". The examinee is required to indicate which one of five alternative drawings represents the "key block" turned to a new position. Working time, 20 minutes.

(9) Similar Figures. In this reference test for the Spatial Relations factor, each of the 80 items presents a set of four two-dimensional figures. Three of the figures show the same design rotated into different positions and a fourth figure shows a similar design which is reversed or turned over. Examinees are required to indicate which figure does not belong to the set of four. Example:



Working time, six minutes.

(10) Addition. This test was included in the analysis as a reference test for the Number factor. Each item requires the examinee to add three numbers, primarily two-digit. The score is the number of correct additions completed in three minutes.

(11) Division. Also designed to measure the Number factor, this test is similar to the above test in that the score is the number of two- and three-digit numbers that have been correctly divided by one-digit numbers in three minutes.

(12) Subtraction and Multiplication. A third reference test for the Number factor, this test requires the completion of as many subtraction and multiplication problems as possible in three minutes.

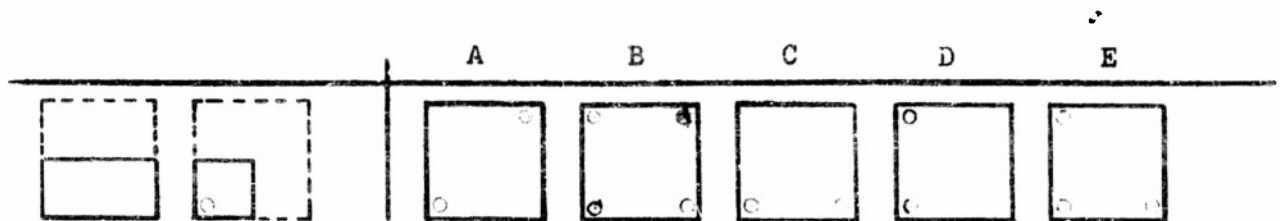
(13) Cancellation. In this test for the Perceptual Speed factor, examinees are required to cross out as many A's as possible on a page of closely-spaced capital letters of the English alphabet. Working time, three minutes.

(14) Number Checking. In this second test of Perceptual Speed, examinees are required to compare pairs of numbers and to mark those that are not identical. The score is based on the number of pairs correctly marked in three minutes.

(15) Similar Rotations. In this test of the Visualization factor, each of the 35 problems consists of eight drawings. The first two are drawings of the same solid figure in two different positions. Drawing 3 represents a different solid figure. The examinee is required to decide how the figure in Drawing 1 was rotated to make Drawing 2, then to rotate Drawing 3 in the same way, and finally to decide which one of the last five drawings shows how Drawing 3 looks after it has been so rotated. Working time, 10 minutes.

(16) Paper Folding. This test was also included as a reference test for the Visualization factor. It consists of 20 items of increasing difficulty. In each problem two figures at the left indicate how a square piece of paper has been folded. A circle in the second figure represents a hole that has been punched through all the thicknesses of paper. One of the five figures at the right represents how the paper will look when it is unfolded after the hole has been punched. Examinees are to indicate which one of the five figures is the correct representation.

Example:



Working time, 10 minutes.

(17) Surface Development. In this third test of the Visualization factor each problem is presented in two figures. One is a drawing of an irregular solid and the other is a pattern which can be cut out of a flat sheet of paper and folded on the dotted lines so that it matches the surface of the solid. Examinees are asked to identify the edges of the solid that correspond to given edges of the pattern. The test includes five problems requiring a total of 20 answers.

Working time, 15 minutes.

(19) Operations. This is one of the tests administered during the Operations Course at the school. Scores were included in the present analysis because the tasks involved appeared to be closely related to those required by the Relative Movement Test. The examinee is supplied with maneuvering board forms, dividers, parallel rulers, and scratch paper. The test form describes six different situations involving the maneuvers of ships. The examinee is required to answer several specific questions as to the bearing, distance, course, or speed of one or more ships involved in the described maneuvers. Five minutes are allowed to complete each of the six sets of sub-answers. No credit is given for the plots themselves.

(20) Directional Plotting. This test was modeled after an Army Air Forces Classification Test of the same title (2, pp. 681-682) and adapted for experimental use in the present analysis. It was included partly because it involves tasks similar to those aspects

of the Relative Movement Test which require the location of points without the aid of plotting or calculating on paper, and partly because a spatial function, not very clearly present in the Spatial Relations tests, appeared to be involved in both this test and in Relative Movement. This function had been isolated in Army Air Forces research and tentatively identified as the Spatial Reference factor. It was discovered in tests similar to this and the following one. For each of the 30 items of the Directional Plotting Test, the examinee is given the coordinates of two points which he is to locate with the aid of the chart before him, but without marking it. He then indicates the direction of the second point from the first in terms of a 12-point compass rose. Working time, 10 minutes.

(21) Plotting. This test was also modeled after an Army Air Forces Classification Test (2, pp. 684-686) and adapted for experimental use. It was included in the present analysis for the same reasons as the Directional Plotting Test. In each of the 25 items of the test, the examinee is given the coordinates of a point. He is to move the point from this starting position to first one location and then to others in consecutive order. The direction and distance of movement is indicated for each stage. All required movements are to be completed with the help of a chart but without actual plotting. The examinee is to indicate the direction of the final position from the starting position in terms of the eight principal compass points. Working time, 15 minutes.

The remaining nine tests were developed and included in the analysis in order to explore the existence of factors in the cognitive area of integration-judgment-planning.

(22) Alternating Operations. This experimental test was designed to measure an integration factor similar to those previously isolated in research by the Army Air Forces Aviation Psychology Program (2, ch. 10). A major characteristic of this test, as well as of Tests (23) and (24), is the set of complex instructions that must be read and understood before the problems can be correctly solved. Solution of the problems requires

the examinee to apply the given rules, to pay attention to a variety of cues, and to change mental set when required. Examinees are presented with a series of 6 to 12 numbers for each item. According to the directions, the following operations must be performed with each succeeding number in the given order -- add, divide, subtract, multiply, and so on. However, when the result equals the next number given, the order of operations is reversed, beginning with multiply. Another equality restores the original order of the operations. Further, when a zero appears at the step requiring division, the zero is omitted and division proceeds with the next number if it is even. But if the next number is odd, the division operation is omitted entirely and the series is continued with the next operation. And finally, if division results in a fraction, the fraction is rounded up to next highest whole number before the following operation is performed. Examinees are required to read the directions, do each of the ten problems, and select the correct answer out of the five given choices. Working time, including the reading of directions, 20 minutes.

(23) Spatial Rotation. This is another experimental test of an integration factor. It also includes a set of complex instructions. For a given item, examinees are presented with a two-dimensional figure having areas of black, white, and grey. The figure must be manipulated mentally according to given instructions such as 90 degree clockwise rotation (or counterclockwise), 180 degree rotation, right-left reversal, or up-down reversal. Two instructions are given for each problem and the examinees are to choose which of five drawings correctly represents the figure so manipulated. However, three additional rules are given governing the final shadings of the areas which may or may not be altered. These concern the position of the black portion after the first operation as well as the nature of the second operation. The test consists of 10 problems. Working time, including the reading of directions, 20 minutes.

(24) Artificial Language. This is a second form of an ETS test of the same title. It was included as the third experimental test of an integration factor. The examinee is asked to translate English verb forms into artificial verb forms using a set of five rules governing

tense, number, person, and selection of letters for verb endings. Ten problems are given. Working time, including direction and rule reading, 20 minutes.

(25) Time and Distance Estimations. This test of 24 items is very similar to the Army Air Forces Practical Estimations Test (2, pp. 133-135). It was included in the present analysis as an experimental measure of a judgment factor. In each item examinees are asked to decide which of five objects, commonly seen in day-to-day living, is either shortest (or longest) or which one of five activities would take least (or most) time to accomplish. Working time, 15 minutes.

(26) Practical Judgment. This 15-item test was included as a second experimental measure of a judgment factor. Each item describes a reasonable problem situation involving social relationships or minor emergencies and then lists four alternatives for best action. Examinees are to judge which one of the four suggested modes of action would be most satisfactory. Working time, 15 minutes.

(27) Judgment of Persons. This third experimental test of a judgment factor requires the examinee to judge what traits best distinguish between people engaged in certain types of occupations. Each item presents two occupations together with a set of five personality traits or interests. The examinee is to pick two traits, one for the first occupation and one for the second, which are most typical for each and which also best distinguish the one occupation from the other. Each of the 12 items list different pairs of occupations and different sets of traits. A total of 24 responses is possible. Working time, 15 minutes.

(28) Skywriting. This test was modeled after an Army Air Forces Classification Test entitled Planning Air Maneuvers (2, pp. 170-174). It was altered and adapted for experimental use in this analysis as a measure of a planning factor. The examinee is to assume he is a skywriting pilot who must plan the shortest, simplest, and most direct path a plane may take to write two adjacent letters, keeping in mind certain rules governing starting and finishing positions,

completion of the first letter before going on to the second, and maximum sharpness of turn. The examinee must select the best path of flight and indicate the direction of travel at several points on each letter-pair. The test consists of 10 pairs of letters and has 32 score points. Working time, 15 minutes.

(29) Square Completion. Also modeled after an Army Air Forces Classification Test (2, pp. 177-180), this test, originally entitled Competitive Planning, was altered and adapted for experimental use as a second measure of a planning factor. For this test, based on the Completion-of-Squares game, the examinee is to plan alternating moves for two contestants so that each completes as many squares as possible for himself. The 20 items consist of groups of four squares in various stages of completion. The rules require "Black" to make the first move and each contestant to make one additional move after the completion of a square. The answer for each item is the number of squares "Black" can complete under the given conditions. Working time, 15 minutes.

(30) Route Planning. This test was designed to be the third experimental measure of a planning factor. A map of a hypothetical small town is presented and the examinee is to assume he has to plan best routes to take in order to complete a series of deliveries and other errands in connection with his job at a hardware store. Points of delivery and other reference points are indicated on the map. Best route is defined as the one requiring a minimum of total distance to be travelled as well as the one that results in heavier articles being transported a minimum of distance. For each of the 13 problems, the examinee must read the background material, consult the map for locations, and then choose the best one of the four alternative answers to the question. Working time, 15 minutes.

Product-moment intercorrelations were computed for all 32 variables and are given in Table 1. Ten reference factors were extracted by means of the grouping method described by Thurstone (5, ch. 5). Grouping was carried out without permitting variables

31 and 32 to influence the location of reference axes although loadings of these two variables on all factors were computed. This procedure avoided the possible appearance of a doublet factor for Relative Movement. No further extraction of factors seemed indicated as the residuals remaining were very small, the highest being .054. The loadings of the 32 variables on the ten orthogonal reference factors, communalities (h^2), means (M), and standard deviations (σ) appear in Table 2. The reference factors were rotated to produce a simple structure with oblique axes by means of the electronic Matrix Rotator located in the Statistical Research and Analysis Section on the Personnel Research Branch of the Adjutant General's Office.

Results and Discussion

Table 3 gives the loadings on the rotated factors; Table 4, the final transformation matrix, and Table 5, the intercorrelations among the factors. The number of zero or near-zero loadings in each column of the rotated factor matrix indicates that a fair simple structure was obtained in the rotation.

The communalities (Table 2) indicate that the common factor variance for several of the variables (20, 24, 25, 26, 27, 28, 29, 30) in this study is very low. The low communalities may be due to low test reliability and consequent high error variance, or to high specificity. Most of the communalities, however, are sufficiently high to indicate that the factors found in this study explain a reasonably good proportion of the total variances of most of the tests.

Interpretation of Factors. The relatively high loadings in each column of Table 3 have been underlined to facilitate ready reference to them in the discussion. Each factor is interpreted as some function involving the variables with underlined loadings.

Factor I is clearly the expected Number factor. The Mathematics Test has some loading on this factor. The Number factor is characterized by an ability to use numbers in simple arithmetic operations.

Table 1
Intercorrelations of Tests

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1. Mathematics																																
2. Figure Analogies	.45																															
3. Letter Sets	.26	.31																														
4. Locations	.27	.27	.22																													
5. Vocabulary	.09	.10	.20	.04																												
6. Verbal Reasoning	.29	.24	.26	.15	.73																											
7. Block Assembly	.52	.38	.20	.19	.11	.24																										
8. Block Recognition	.36	.41	.18	.23	.02	.18	.57																									
9. Similar Figures	.33	.33	.26	.25	-.02	.18	.44	.49																								
10. Addition	.17	.04	.19	.11	.04	-.01	-.02	-.05	.10																							
11. Division	.37	.09	.18	.14	.04	.08	.03	.07	.16	.70																						
12. Subtraction and Multiplication	.20	.02	.15	.14	.05	.02	-.05	-.04	.12	.78	.70																					
13. Cancellation	.16	.14	.17	.16	.10	.15	.10	.10	.21	.28	.24	.47	.50																			
14. Number Checking	.13	.15	.20	.20	.04	.01	.06	.08	.20	.46	.42	.47	.50	.19																		
15. Similar Rotations	.32	.40	.25	.32	.09	.20	.35	.48	.36	.06	.15	.06	.18	.19	.43																	
16. Paper Folding	.40	.48	.27	.24	.00	.20	.48	.55	.39	-.04	.05	-.05	.14	.13	.43	.43																
17. Surface Development	.35	.45	.18	.26	.02	.14	.49	.60	.39	-.08	.00	-.08	.12	.10	.42	.57	.36															
18. Relative Movement	.52	.39	.22	.30	.13	.30	.38	.36	.30	.11	.24	.09	.16	.14	.35	.42	.36	.29														
19. Operations	.39	.27	.20	.23	.04	.13	.26	.27	.22	.09	.16	.11	.14	.16	.24	.27	.29	.26	.24													
20. Directional Plotting	.25	.28	.22	.17	.08	.14	.24	.22	.19	.20	.17	.20	.10	.18	.21	.23	.22	.22	.26	.26												
21. Plotting	.27	.30	.21	.19	-.01	.04	.25	.20	.26	.28	.25	.23	.14	.28	.27	.28	.25	.32	.24	.29	.22											
22. Alternating Operations	.32	.30	.23	.17	.21	.26	.15	.16	.12	.13	.17	.09	.19	.14	.22	.27	.26	.21	.25	.23	.22	.22										
23. Spatial Rotation	.34	.46	.22	.18	.17	.27	.33	.31	.23	.12	.13	.06	.12	.13	.28	.34	.36	.29	.25	.22	.26	.34	.29									
24. Artificial Language	.25	.24	.19	.11	.26	.34	.13	.12	.08	.02	.06	.04	.10	.09	.16	.19	.17	.19	.10	.14	.13	.23	.29	.29								
25. Time and Distance Estimations	.17	.18	.05	.08	.09	.14	.16	.21	.14	.00	.07	.01	.02	.00	.20	.19	.18	.19	.07	.14	.12	.10	.13	.06	.02							
26. Practical Judgment	.02	.03	.02	.14	.07	.11	-.01	-.03	.02	.07	.06	.06	-.01	.00	.03	.06	.05	.04	.05	.04	.07	.05	.04	.03	.05	.02						
27. Judgment of Persons	.07	.07	.10	.08	.18	.04	.06	.03	.11	.07	.08	.04	.04	.03	.06	.05	.04	.04	.08	.04	.04	.19	.09	.06	.01	.09	.09					
28. Skywriting	.13	.19	.09	.12	.05	.18	.20	.13	.18	.07	.03	.04	.05	.18	.13	.13	.18	.20	.14	.13	.21	.05	.16	.07	.11	.07	.04					
29. Square Completion	.18	.20	.17	.13	-.01	.03	.17	.16	.18	.10	.13	.08	.02	.04	.16	.22	.12	.16	.15	.10	.08	.12	.12	.00	.07	.05	-.03	.11				
30. Route Planning	.19	.24	.24	.19	.03	.09	.17	.11	.19	.10	.08	.02	.12	.10	.19	.23	.17	.30	.20	.14	.21	.18	.19	.14	.07	.08	.03	.11	.08			
31. Relative Movement (Pretest form)	.50	.51	.25	.26	.15	.30	.43	.45	.33	.05	.16	.03	.12	.14	.34	.53	.46	.59	.33	.30	.36	.33	.42	.27	.23	.02	.06	.26	.13	.32		
32. Relative Movement (Part score)	.45	.44	.20	.22	.17	.33	.37	.37	.25	-.01	.11	-.02	.04	.06	.33	.42	.34	.66	.32	.20	.25	.24	.30	.21	.18	.02	.08	.19	.13	.22		

Factor II is the expected Verbal factor. The tests of Relative Movement and Artificial Language have some loading on this factor. It involves an understanding of word meanings and the relations between words.

Because the reference tests for both the Spatial Relations and Visualization factors did not emerge separately but clustered together to define Factor III, this factor can be tentatively identified as Visualization-Spatial. It would appear to be characterized by an ability both to comprehend the relative arrangement of elements in a positionally altered pattern and to manipulate a visual image mentally.

Army Air Force psychologists (2) as well as other investigators have in the past, however, succeeded in isolating spatial relations and visualization as functions distinct from one another. According to recently proposed definitions (1), the Spatial Relations factor involves the ability to comprehend the relative arrangement of elements comprising a visual pattern after it has been turned, twisted, inverted, or otherwise changed in orientation with respect to the observer. The Visualization factor, on the other hand, involves the ability to manipulate a visual image or pattern.

The distinction between the two functions is oftentimes difficult to control as far as test design is concerned. The spatial relations tests used in this study appear to be measures of ability to recognize patterns when viewed in changed positions. It is entirely possible, however, to do the problems in two of these tests (8,9) by operations defined as "visualization". If many of the examinees had in fact done the problems in these two tests by visualization operations, or all spatial relations and visualization tests primarily by visualization operations in combination with some spatial, one would expect these six tests to emerge together as a single factor which largely represents a visualization function. It is likely that additional tests for each of these factors would be needed to effect a satisfactory separation.

Factor IV is the expected Perceptual Speed factor. It is

Table 2
Loadings on the Unrotated Factors

	I	II	III	IV	V	VI	VII	VIII	IX	X	h^2	M	σ
1. Mathematics	.29	.21	.46	-.11	.27	.41	-.24	-.16	-.03	-.02	.68	29.7	6.9
2. Figure Analogies	.06	.20	.56	.03	.34	.08	.03	.00	.12	-.05	.50	22.5	3.4
3. Letter Sets	.20	.26	.27	.09	.12	.05	.07	.06	.31	.07	.31	14.2	2.3
4. Locations	.15	.10	.34	.10	.05	.24	.06	.33	.05	-.04	.33	14.2	3.8
5. Vocabulary	.05	.85	-.11	-.02	-.03	-.07	.07	-.01	-.01	.08	.75	48.2	7.5
6. Verbal Reasoning	.04	.85	.11	.02	.02	.07	-.08	.01	.01	-.04	.75	52.1	10.1
7. Block Assembly	-.72	.21	.68	-.06	-.06	-.03	.08	-.15	.01	.02	.54	21.7	3.5
8. Block Recognition	-.01	.12	.78	-.09	-.08	-.06	-.05	-.01	-.15	.07	.67	19.2	5.2
9. Similar Figures	.15	.09	.60	.06	-.14	.02	-.02	-.02	.16	.04	.44	22.3	9.1
10. Addition	.88	-.03	-.04	.00	.04	-.09	.10	.02	.08	.03	.80	40.4	8.5
11. Division	.82	.03	.08	.00	.01	.11	-.12	-.04	-.02	.00	.71	41.1	10.7
12. Subtraction and Multiplication	.88	.00	-.04	.00	-.05	-.02	.02	.03	-.04	-.02	.78	55.6	13.7
13. Cancellation	.30	.13	.17	.57	-.01	.01	-.08	-.02	.03	.08	.48	32.9	7.8
14. Number Checking	.52	-.04	.18	.57	.01	-.01	.08	.01	-.02	-.05	.64	49.8	10.8
15. Similar Rotations	.10	.16	.59	.06	.02	.05	.06	.17	.00	-.02	.42	16.8	4.3
16. Paper Folding	-.02	.12	.71	.02	.15	.02	-.06	.00	.08	-.03	.55	11.4	3.0
17. Surface Development	-.06	.10	.73	.00	.10	.00	.00	.02	-.16	.00	.58	13.0	5.4
18. Relative Movement	.17	.24	.48	.01	.06	.39	.04	-.10	.03	-.17	.51	24.5	5.7
19. Operations	.14	.09	.36	.05	.18	.29	.08	-.10	-.03	.23	.35	31.2	6.3
20. Directional Plotting	.22	.12	.29	-.01	.18	.07	.23	-.05	.00	.07	.24	20.7	6.6
21. Plotting	.30	.00	.36	.05	.21	.08	.32	-.07	.00	-.10	.39	13.9	4.1
22. Alternating Operations	.15	.27	.22	.09	.38	.08	.00	.09	.00	.22	.36	5.2	2.4
23. Spatial Rotation	.12	.25	.40	-.01	.43	-.06	.03	-.06	.00	-.01	.43	6.0	2.4
24. Artificial Language	.05	.35	.14	.06	.33	-.02	-.03	-.03	-.01	-.18	.29	3.5	1.7
25. Time and Distance Estimations	.03	.13	.24	-.09	.00	.01	.10	-.01	-.06	-.06	.10	10.8	2.8
26. Practical Judgment	.07	.10	-.02	-.06	.03	.05	.08	.28	.03	-.11	.12	8.1	1.6
27. Judgment of Persons	.10	.21	.02	-.03	.10	-.02	-.03	.19	-.10	.20	.15	15.4	2.0
28. Skywriting	.06	.06	.23	-.04	.03	.08	.27	-.02	-.03	.00	.14	20.4	3.6
29. Square Completion	.12	.01	.24	-.11	.03	.10	.00	.01	.22	.09	.15	11.6	3.7
30. Route Planning	.08	.07	.24	.06	.21	.20	.14	.09	.22	-.05	.24	8.0	2.0
31. Relative Movement (Pretest form)	.09	.26	.57	-.03	.30	.27	.16	-.17	-.06	-.14	.64	35.6	5.8
32. Relative Movement (Part score)	.03	.29	.45	-.10	.14	.47	.07	-.08	-.10	-.21	.60	15.2	2.9

Table 3
Loadings on the Rotated Factors

	I	II	III	IV	V	VI	VII	VIII	IX	X
1. Mathematics	.18	-.01	.01	-.10	.18	<u>.50</u>	.00	-.05	.02	.08
2. Figure Analogies	-.06	-.02	.16	.05	<u>.29</u>	.05	.01	.03	.11	.00
3. Letter Sets	.04	.13	.08	.05	.03	-.07	-.04	-.01	<u>.31</u>	.03
4. Locations	-.01	.01	.00	.15	-.01	.12	-.01	<u>.37</u>	.08	.03
5. Vocabulary	.02	<u>.77</u>	-.02	-.04	-.06	-.09	.05	-.04	-.01	.06
6. Verbal Reasoning	-.02	<u>.70</u>	.03	.03	.04	.09	-.05	.03	.02	-.02
7. Block Assembly	.00	.12	<u>.43</u>	-.02	.00	.00	.11	-.08	.06	-.02
8. Block Recognition	.08	-.01	<u>.57</u>	-.03	.05	.02	.00	.10	-.05	.06
9. Similar Figures	.08	.01	<u>.39</u>	.08	-.07	.01	-.06	.00	<u>.23</u>	-.03
10. Addition	<u>.67</u>	-.02	.01	-.02	.01	-.12	.02	-.03	.07	.01
11. Division	<u>.62</u>	-.01	.00	.00	.02	.18	-.04	-.01	.01	.02
12. Subtraction and Multiplication	<u>.68</u>	.03	-.01	.02	-.03	.01	.01	.03	-.03	-.02
13. Cancellation	-.06	.06	.02	<u>.53</u>	-.03	-.01	-.05	-.01	.06	.06
14. Number Checking	.10	-.04	-.02	<u>.57</u>	.00	-.05	.07	.05	-.02	-.04
15. Similar Rotations	.02	.04	<u>.29</u>	.12	.06	.00	.01	<u>.23</u>	.04	.01
16. Paper Folding	-.05	-.07	<u>.38</u>	.06	<u>.21</u>	.05	-.08	.05	.12	-.02
17. Surface Development	-.05	-.06	<u>.41</u>	.06	.17	.05	.05	.14	-.11	.05
18. Relative Movement	-.01	.17	-.02	.07	.00	<u>.38</u>	.15	.02	.06	-.11
19. Operations	-.04	-.04	-.02	-.01	-.04	.21	<u>.23</u>	-.06	.04	<u>.28</u>
20. Directional Plotting	.09	.04	.03	-.03	.05	-.01	<u>.23</u>	-.02	.00	.11
21. Plotting	.09	-.02	.00	.07	.11	-.01	<u>.29</u>	-.01	-.03	-.05
22. Alternating Operations	-.01	.02	-.01	.04	<u>.21</u>	.00	.03	.06	.01	<u>.30</u>
23. Spatial Rotation	.04	.02	.14	-.01	<u>.40</u>	-.04	.02	-.04	-.03	.05
24. Artificial Language	-.04	.20	-.03	.09	<u>.35</u>	.03	-.04	.00	.07	-.11
25. Time and Distance Estimations	.05	.12	.11	-.05	.02	.02	.10	.04	-.05	-.04
26. Practical Judgment	.06	.09	-.07	-.01	.03	-.03	-.03	<u>.27</u>	.00	-.06
27. Judgment of Persons	.10	.06	.05	-.06	.04	-.06	-.03	.17	-.07	<u>.26</u>
28. Skywriting	-.01	.08	.01	-.03	-.05	.00	<u>.26</u>	.02	-.02	.02
29. Square Completion	.10	-.07	.11	-.13	-.03	.04	-.04	-.03	<u>.25</u>	.05
30. Route Planning	-.09	-.02	-.09	.06	.08	.06	.06	.07	<u>.20</u>	-.02
31. Relative Movement (Pretest form)	-.06	.12	.02	.01	.20	.26	.28	-.05	-.06	-.04
32. Relative Movement (Part score)	-.09	.21	-.11	-.02	.05	.47	.24	.08	-.07	-.09

Table 4

Final Transformation Matrix

	I	II	III	IV	V	VI	VII	VIII	IX	X
1.	.77	.00	.00	.00	.00	.03	.00	.00	.01	.00
2.	-.04	.87	.00	.00	.00	.00	.00	.00	.00	.00
3.	.00	-.16	.60	.07	.11	.03	.00	.11	.03	-.01
4.	-.52	.00	-.19	.96	-.05	-.08	.01	.00	-.01	.00
5.	-.12	-.34	-.29	-.06	.78	-.03	.01	-.05	-.13	.20
6.	-.27	.02	-.65	-.01	-.37	.85	.31	.12	.08	.15
7.	-.19	.24	-.26	.00	-.29	-.36	.80	.00	-.07	.00
8.	.04	-.10	.03	.11	.04	-.22	-.33	.94	.01	.13
9.	-.09	-.05	.02	-.07	-.06	-.22	-.36	-.27	.93	-.23
10.	-.01	-.18	.14	-.25	-.37	-.17	.13	-.15	.16	.93

Table 5
Intercorrelations of Factors

	I	II	III	IV	V	VI	VII	VIII	IX	X
I.		.04	-.15	.53	.14	.07	.23	.00	.27	.18
II.	.04		.10	.08	.36	.16	.01	.06	.19	.37
III.	-.15	.10		.14	.27	.53	.46	.19	.26	.05
IV.	.53	.08	.14		.21	.22	.26	-.06	.30	.31
V.	.14	.36	.27	.21		.37	.55	.25	.58	.32
VI.	.07	.16	.53	.22	.37		.34	.16	.36	.16
VII.	.23	.01	.46	.26	.55	.34		.40	.64	.00
VIII.	.00	.06	.19	-.06	.25	.16	.40		.41	-.05
IX.	.27	.19	.26	.30	.58	.36	.64	.41		.20
X.	.18	.37	.05	.31	.32	.16	.00	-.05	.20	

characterized by speed of picking out a given symbol wherever it is found among a mass of other symbols, and by speed of discriminating differences between symbol patterns. This factor is most highly correlated (.53) with the Number factor. Speed of perception is quite likely involved in both.

Factor V appears to be an integration factor as defined by the three experimental tests of Integration. It is characterized by an ability to assimilate complex instructions in a limited time and to apply them successfully. Tests obtaining the relatively high loadings on this factor are the three Integration Tests, Figure Analogies, and Paper Folding. The Mathematics Test also has some loading on this factor. All have complex instructions in common. Both the correlation of .36 between this factor and the Verbal factor (Table 5), and the verbal nature of the function held in common by the tests defining this factor suggest that it may be closely related to reading comprehension. The absence, in this analysis, of reading comprehension tests, however, has left this possibility unexplored.

Factor VI is apparently the General Reasoning or Mathematics Reasoning factor as characterized by the tasks required in the Officer Classification Battery Mathematics Test. Relative Movement, which also involves the use of mathematics, obtains a relatively high loading on this factor. Tests of Operations and Division also have some loading on this factor.

Factor VII appears to be a spatial factor characterized by an ability to determine movement and/or final position of points in two-dimensional space within the framework of instructions specifying location, distance, direction, or other conditions. It appears to be the Spatial Reference factor previously isolated and tentatively identified by Army Air Force psychologists (2). It is defined by the tests of Operations, Directional Plotting, Plotting, and Sky-writing. Common to three former tests is the ability to determine, on the basis of relevant information, the final location of points in space relative to each other. Common to Operations, Plotting, and Sky-writing is the ability to trace the movements of points in space along paths involving a series of specified changes in direction.

It should be noted that the Spatial Reference factor had been isolated by Army Air Force psychologists (2) in the course of an analysis of a battery that did not include the Skywriting Test or any of the other Planning Tests, and further that Army Air Force Planning Batteries did not contain any of the Plotting Tests. The present analysis indicates that the Plotting Tests have some function in common with the Skywriting Test.

Table 5 shows a correlation of .46 between this factor and the Visualization-Spatial factor (III). Both are characterized by an ability to comprehend relationships among elements in a spatial pattern and to manipulate the pattern. For Factor III, however, the pattern as a whole is spatially shifted but otherwise essentially unaltered, whereas in Factor VII the final character of the pattern depends on the location of elements or the moving about of the elements. Also shown in Table 5 is a correlation of .55 between this factor and the tentatively identified Integration factor (Complex Instructions). The reason for this may be that of the nine tests which have relatively high loadings on one or the other of these factors, all but one also involve problems of a spatial or visualization nature.

Factor VIII is defined by Locations, Similar Rotations, and Practical Judgment. Its correlation of .40 with Factor VII (Spatial Reference) suggests that it is some kind of space factor. This is supported by the presence of Similar Rotations and Locations (if Locations is considered to involve judgment of spatial patterning). Communalities and loadings for all four defining tests are not very high, however. Respective communalities are .33, .42, .12, and .15. Had both loadings and communalities been higher it might have been possible to identify this factor as a judgment factor. Since the evidence is not clear, it seems best to leave it uninterpreted.

Factor IX is correlated .64 with Factor VII (Spatial Reference) and .58 with Factor V (Perceptual Speed). It is defined by Letter Sets, Similar Figures, Square Completion, and Route Planning. The

presence of two of the experimental Planning Tests suggests that this might be a planning factor. The presence of Similar Figures (Spatial) further suggests a planning-in-space function somewhat related to Spatial Relations. As with Factor VIII, loadings and communalities tend to be low and no clear evidence is available for interpreting this factor.

Factor X correlates most highly with the Verbal factor (.37) and is defined by Operations, Alternating Operations, and Judgment of Persons, all of which involve a certain degree of verbal comprehension ability. It may be some kind of verbal factor but it is best left uninterpreted.

Further information about the rotated factors can be obtained from Table 5 which shows their intercorrelations. Many of these coefficients are quite high. These intercorrelations could be factor-analyzed to yield second-order factors. Inspection of the table indicates that Factors III, V, VI, VII, VIII, and IX tend to be fairly highly intercorrelated. Since 22 of the 25 tests having high loadings on one or another of these intercorrelated factors involve mathematical or spatially-related tasks, a second-order factor characterized by spatial and mathematics ability suggests itself as a possibility. A second-order speed factor may possibly explain the correlation of .53 between the Number factor (I) and the Perceptual Speed factor (IV). And finally, the correlation between Factors I and X might be explainable by a second-order verbal factor.

Factorial Composition of the Relative Movement Test. Inspection of Table 3, which shows the loadings for the tests on the 10 factors, indicates that the Relative Movement Test (variable 18) obtains loadings on three of the factors isolated in the present study. Its highest loading (.38) is on the Mathematics Reasoning factor (VI). It obtains a loading of .17 on the Verbal factor (II) and a loading of .15 on the Spatial Reference or Plotting factor (VII).

The pattern of loadings for Relative Movement when scored so

as to include only those items completed by a majority of examinees (variable 32) is very similar except that the loadings tend to be higher. Although partly scoring the Relative Movement Test eliminates the effect of speed in a restricted sense, it does not remove the attitude of speed that was present during the testing. Relative Movement, partly scored, has loadings of .47 on the Mathematics Reasoning factor, .21 on the Verbal factor, and .24 on the Spatial Reference or Plotting factor. Scoring on the first 20 items resulted in almost doubling the loading on Mathematics and increasing the loadings on Verbal and Spatial Reference. It also resulted in decreasing the loading on Perceptual Speed from .07 to -.02.

It is interesting to note that the findings with respect to the presence in the operational Relative Movement Test of a spatial function and a general reasoning or mathematics function are consistent with the results of an earlier analysis of Relative Movement by a different approach (3). The earlier study involved the analysis of the responses of a sample of individuals who had taken the test and who were later asked individually to do the problems aloud in an interview situation.

The pretest of new Relative Movement items (variable 31), administered under conditions that minimized the necessity of working rapidly, obtained loadings on four factors: .28 on Spatial Reference, .26 on Mathematics Reasoning, .20 on the tentatively identified Integration or Complex Instructions factor (V), and .12 on Verbal.

Unlike the speeded Relative Movement measures, the unspeeded measure has a loading on Factor V even though the complexity of test instructions and item-statements appear to be at essentially the same level for all three tests. Like the pretest of Relative Movement items, the Mathematics Test is also relatively unspeeded (this was one of the findings of an earlier study, 3, pp. 3-4) and it has a loading (.18) on the Complex Instructions factor (Table 3). And finally, the items of the Mathematics Test are similar to those of Relative Movement to the extent that they

present fairly complex problem situations which must first be comprehended before answers can be formulated.

One hypothesis to account for the appearance of Factor V in the unspeeded Relative Movement measure might be that this factor, which appears to involve an ability to integrate meaningfully the elements of a verbally-given problem situation, emerges when speed of work does not enter into the total score.

A related hypothesis to account for the lower Mathematics loading of the unspeeded Relative Movement measure, as compared to the speeded measure (.26 as compared to .38), and the additional loading on Factor V, might be that with ample time those individuals having low mathematics facility succeed by using non-mathematical methods. The total score would then depend less on mathematics ability than when conditions are speeded enough to make these non-mathematical methods too slow to contribute very much to the total score.

Summary of the Factorial Composition of the Relative Movement Test. Table 6 gives the loadings above .10 for the three separate measures of Relative Movement on the four factors found to be involved.

Table 6
Summary of the Factorial Composition of
the Relative Movement Test

	Ver- bal	Complex Direc- tions	Mathe- matics	Spatial Ref- erence
	II	V	VI	VII
Relative Movement	.17		.38	.15
Relative Movement (part score)	.21		.47	.24
Relative Movement (Pretest form)	.12	.20	.26	.28

The present Relative Movement test was found to be primarily a

measure of mathematics ability. Also measured by this test is verbal ability and a function identified as Spatial Reference or ability to deal with changes in distance and direction of objects moving in two-dimensional space.

Scoring the Relative Movement Test on only the first 20 items resulted in making it a slightly stronger test of Verbal, Mathematics, and Spatial Reference than when all 50 items were scored.

The pretest of a new parallel form of Relative Movement, administered under essentially unspeeeded conditions, was also found to be a measure of the Mathematics, Spatial Reference, and Verbal factors. This measure of Relative Movement was found to differ from the operational form to the extent of having lower loadings on Mathematics and Verbal and having a loading on one additional factor (Integration or Complex Instructions) which appears to involve an ability to deal with the details of verbally-given instructions or to grasp the elements of verbally-given problem situations.

Summary and Recommendations

Summary. The present study was undertaken to identify the psychological functions measured by the Relative Movement Test, which is a part of the U. S. Navy Officer Classification Battery. A factor analysis was performed based on a correlation matrix containing 30 test scores. Among these scores were those of standard factorial reference tests and other experimental tests. All tests had been administered to 666 officer candidates at the U. S. Navy Officer Candidate School.

Ten factors were extracted and loadings were obtained for three separate measures of Relative Movement -- (1) the regular form of the test, (2) the regular form scored on the first 20 items, and (3) an unspeeeded pretest of new Relative Movement items.

The findings were as follows:

1. All three measures of Relative Movement obtained relatively high loadings on the following factors: Mathematics, Verbal, and a spatial factor which is

found in plotting tests and which was tentatively identified as Spatial Reference. It is characterized by an ability to deal with changes in distance and direction of objects moving in two-dimensional space.

2. The Mathematics factor was found to be most important, both in the regular form of Relative Movement and in the partly-scored regular form. The Verbal and Spatial Reference factors were of approximately equal importance.

3. All three measures of Relative Movement obtained zero or near-zero loadings on the Visualization-Spatial factor as characterized by standard spatial and visualization tests.

4. The unspeeeded pretest of a new parallel form of Relative Movement differed from the other two forms to the extent of having lower loadings on the Mathematics and Verbal factors and having a loading on one other factor. This additional factor is characterized by an ability to deal with complex instructions or to grasp the elements of a fairly complex problem situation. Highest loadings were obtained on both Mathematics and Spatial Reference, and the lowest of Verbal.

Recommendations. Since the Relative Movement Test would appear to be a measure of two factors already represented by tests in the Officer Classification Battery (Mathematics Reasoning and Verbal), and since the unique function measured by Relative Movement was found to be the Spatial Reference factor as defined by the plotting tests, (which obtained zero or near-zero loadings on both Mathematics Reasoning and Verbal), it is recommended that a validity study of tests of the Spatial Reference factor be performed. Such a study should provide for a comparison of validities for the Relative Movement Test and tests similar to the plotting tests. A validity study

would provide evidence of whether a Spatial Reference test would increase the predictiveness of the Officer Classification Battery enough to warrant its inclusion in the battery together with or in place of the Relative Movement test.

Further research is needed in order to gain a clearer understanding of the nature of Factor V. The inclusion of scores for reading comprehension tests in an intercorrelation matrix of the tests found to have loadings on Factor V might indicate whether this factor can be more positively identified as an integration factor or whether it is more related to verbal comprehension. Further research is also needed in order to explore the nature of Factors VIII, IX, and X.

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